River St. Substation Failure
Fitchburg Gas & Electric Company
June 25, 2001

Preliminary Investigation Summary
River Street Substation Summary

At or about 05:49 a squirrel caused a fault on the 13.8 kV Bus at the Bypass switch for the 25W29 recloser. The primary interrupting device, the 69kV oil circuit breaker (OCB) located on the 69kV side of the transformer was found in the closed position. The OCB trip coil was still burning. The fault, located on the 13.8 bus at River St. Substation (SS), was isolated via the relay at the 69 kV source Line 03 from Flagg Pond Substation. The loss of the 03 line also de-energized Princeton Rd. Substation. Total customer outage at 05:54 was 3751. First responders were sent to Flagg Pond SS acknowledging the station alarm (115 – 69 kV station alarm). Fitchburg Fire Department notified FG&E of a fire at the River Street Substation. The fire was still burning as our crews arrived. Fires were extinguished and oil containment procedures were put in motion. The Massachusetts Department of Environmental Protection was notified of a potential release greater than ten gallons well within the two-hour limit. Distribution restoration switching began once damage assessment was complete. . 69 kV Line 03 at Flagg Pond and Princeton Rd Substation were re-energized 23 minutes later restoring 174 customers. Circuits 25W27 & 25W28, emanating from River Street Substation were tied at various locations to circuit 50W52 and energized from Princeton road substation at 09:15 restoring all but one customer Munksjo Paper (Circuit 25W29). The mobile substation was disconnected from the Beech Street substation and relocated at River St. Substation to restore Munksjo Paper at 14:15

Current Conditions

As of 16:00 Thursday 6/26/01 the River St. Substation is de-energized. The 69 – 13.8 kV Mobile substation is carrying the Munksjo Paper company . The terminations from circuits 25W27, 25W28 and 25W29 are disconnected from the River Street substation structure. 69 kV lines 03 and 01 are energized up to the open disconnects located at the River St. Substation. 25W27 & 25W28 are presently being supplied via circuit 50W51 from Princeton Road Substation. Transformer, tap changer and 69 kV OCB oil samples were taken the same day of the incident and have been sent out for testing.

Oil clean up is still in progress, the site has been cleared to remove up to 25 yards of waste material. FG&E has contracted Cyn Environmental to perform the work and GZA (our LSP) is managing the remediation. It appears that the volume of oil release was less than originally expected. The estimated total oil release from the transformer main tank is approximately 15-20 gallons.

Information gathering on all equipment has been initiated. Engineering will be continuing to investigate and report on coordination, protection and detailed chronological explanation of the events leading up to this failure. Testing and evaluation on the transformer is scheduled to begin this morning 6/27/01. The 69 kV OCB will be tested evaluated and repairs will be scheduled according to the findings. The bushings, lightning arresters, and insulators on the 69 kV and 13.8 kV bus as well as the circuits 25W27, 25W28 & 25W29 reclosers will be tested and evaluated. Currently plans are being developed and evaluated as a team on best course of action(s) to enable the removal of the mobile substation as soon as possible. Another meeting will be convened Thursday 6/28/01 to analyze the findings and assess options.

Fault and Protection System - Sequence of Events

The original fault occurred across the middle phase of the 13.8kV Bypass switch on the 25W29 circuit supplying Munksjo Paper. Because the fault involved both sides of the switch, it was necessary for the circuit recloser and the transformer 69kV breaker to trip in order to clear the fault. The 25W29 circuit recloser tripped, but did not reclose, due to the loss of AC closing voltage. The station service transformer is supplied from the faulted phase.

The 69kV overcurrent relays also operated correctly to trip the breaker. However, the breaker failed to open. The next (Back-up) interrupting device was the Line 03 breakers at Flagg Pond.

Due to the high impedance of the fault and the impedance of the River St. transformer, the relays at Flagg Pond did not operate on the original fault. After some time the continuous fault current caused the secondary windings of the transformer to fail. When the transformer secondary winding failed, the fault current increased to a level that caused the (SEL351) Overcurrent relay at Flagg Pond to pick-up.

The SEL351 relay sent a trip signal to the Line 03 breakers (7B1 and 7B2) 51 seconds after the River St. Transformer secondary winding failed. Both breakers then tripped, and 7B1 reclosed..

The fault at this time was permanent. Therefore the Flagg Pond breaker closed back into the fault. Twenty-six seconds after the Flagg Pond breakers reclosed, the River St. transformer experienced a failure in the high side winding, causing the fault current to increase significantly. 0.2 seconds after the high side winding failed, breaker 7B1 at Flagg Pond tripped again and locked-out.

Refer to the attached Appendix A - Sequence of Events and Appendix B - Fault Current Graphs for more detail.

Relay Operation Analysis:

The following tables list the relay targets found and the breaker operations recorded after the event

River St.

Device	Relay Target	Breaker Status	Number of Operations
Battery Charger	Low DC voltage		
25W27	None available	Open	1
25W28	None available	Open	1
25W29	Phase B Overcurrent, Instantaneous Ground Overcurrent	Open	1
69kV Breaker	Phase A,B,C, Overcurrent	Closed	0

Flagg Pond

Device	Relay Target	Breaker Status	Number of Operations
Line 03	SEL 351 Phase A, B, Gnd directional. overcurrent	7B1 Open 7B2 Open	2 1

All protective relays operated as designed. However, Breaker 7B2 did not reclose as designed and the lack of reclosing of the River St. reclosers is questionable.

River St.:

The original fault was outside the transformer Differential zone of protection, therefore the only local relaying to operate for the fault was the Circuit 25W29 and the transformer high side overcurrent relays. The 25W29 relay operated to trip the recloser. The recloser did not close. This may have been due to the loss of station service voltage (the station service transformer is located on the faulted phase). The transformer high side overcurrent relay operated to trip the 69kV breaker. However the breaker failed to trip.

During station inspection after the event, the crew found that the breaker trip coil was burned, the battery voltage alarm activated and there was corrosion on the battery charger. It is not known whether the damaged trip coil caused the battery voltage to deteriorate to a point that no other tripping could be performed, or if the low DC voltage caused the trip coil to burn-out.

While there was station service present there was enough DC Voltage to trip the first breaker (25W29).

Because the high side breaker did not trip, the through fault current caused the transformer to fail. At this time the transformer differential relay probably operated, but there was no DC voltage to trip the lock-out or drop a target on the differential relays.

Flagg Pond:

The Flagg Pond relays operated as designed. Although the relay operation time of the Flagg Pond relays was long, the operating time can not be reduced without causing miscoordination between River St., Princeton Road, and Flagg Pond. The Flagg Pond relays are set as back-up to protect the 69kV line and Flagg Pond equipment against damage due to an uncleared remote fault. The existing design of back-up relaying does not include protection of remote equipment due to breaker failure.

Reclosing:

The reclosing of the Breaker 7B1 operated correctly. The reclosing of 7B2 should be tested.

Line 03 is fed from Breakers 7B1 and 7B2. Breaker 7B1 is tied to Bus 1 and is considered the primary breaker for reclosing Line 03. Breaker 7B2 is the middle breaker in the breaker-and-a-half scheme and is considered the secondary breaker for reclosing of Line 03.

Breaker 7B1 reclosing is performed by the SEL279 relay which also supervises the reclosing of the 7B2 relay. While the SEL279 relay is in its timing sequence or locked-out, a normally closed contact of the SEL279 relay opens to inhibit the reclosing of the 7B2 breaker.

The SEL279 relay is set to automatically reclose the 7B1 breaker after 5 seconds and 15 Seconds after the initial trip on a Hot Bus- Dead-Line condition. The second reclosure was not initiated since the breaker was still closed 15 seconds after the initial trip.

The 7B2 reclosing is performed by an RC relay which is supervised by the 79CO switch and the SEL279 relay. While the SEL279 relay is in its timing cycle or locked-out, the reclosing of 7B2 is inhibited.

The 7B2 should have reclosed after the 7B1 breaker closed. This scheme should be tested.

The Protection and Control Team will investigate the possibility and feasibility of adding relaying to provide remote breaker failure protection. A local Breaker Failure scheme at River St. is not possible since the next interrupting device is at a remote location. The standard remote breaker failure scheme requires costly communication equipment between stations.

The PC&M team will also explore revising the setting of the reclosing relays at Flagg Pond.

Recommendations:

The Protection, Control, and Measurements (PC&M) team recommends the following actions be taken.

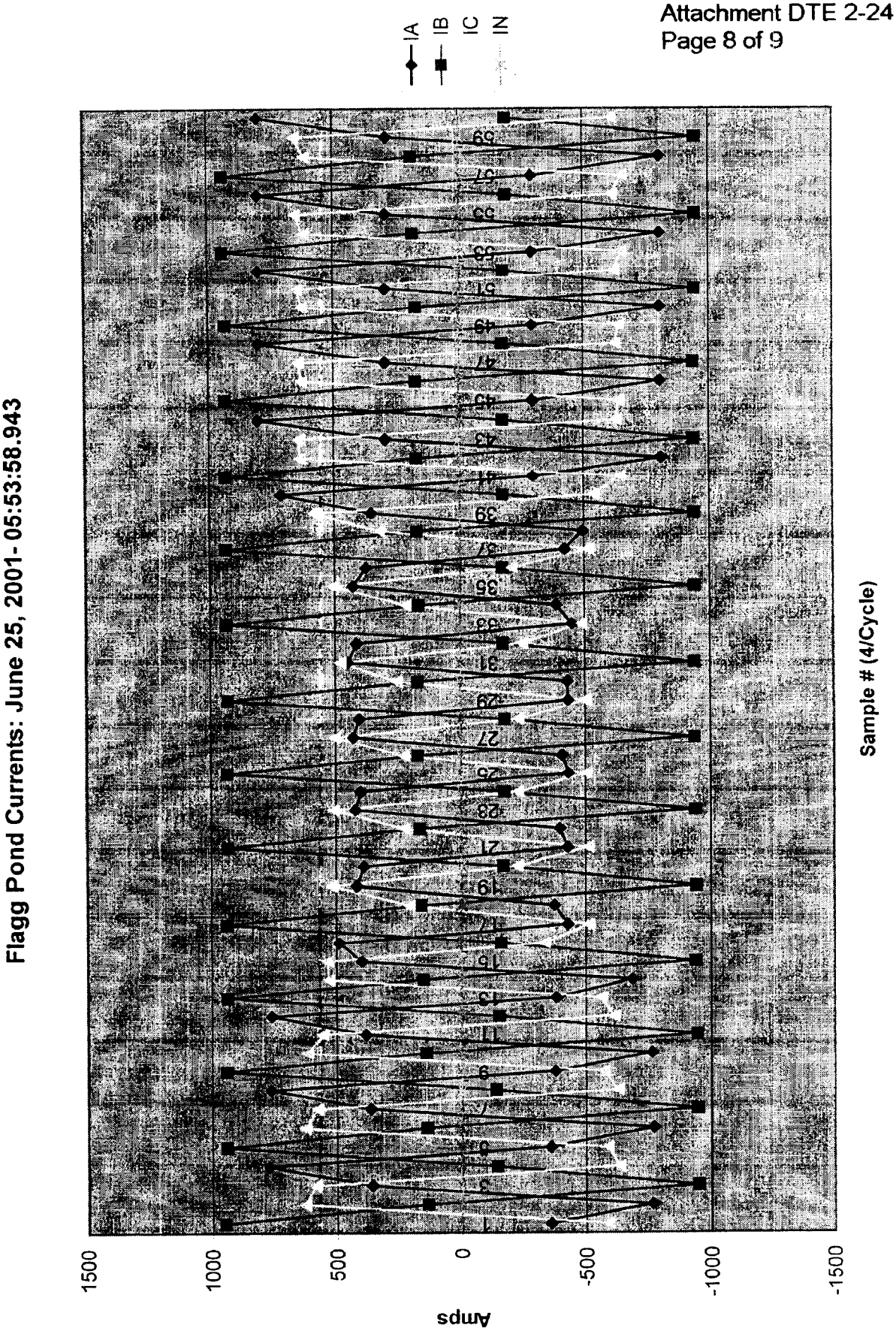
- The Engineering Department investigate adding relaying or protection logic to perform remote station breaker failure.
- The engineering Department perform a battery sizing calculation for the River St. Battery. The battery should be sized to trip all breakers at Rivers St. at the same time and then provide 8 Hours back-up power for normal station DC load.
- The engineering department include a second trip coil in the specification of future purchases of 69kV breakers and circuit switchers where no local breaker failure protection is possible.
- FG&E perform operational testing of all relays, breakers and reclosers at River St. The PC&M team will issue relay settings for testing purposes.
- FG&E load test the River St. battery and test the battery charger.
- FG&E hire a contractor to test the reclosing scheme of the 7B2 breaker at Flagg Pond. During the test the system conditions experienced during this event should be simulated

Appendix A – Sequence of Events
Flagg Pond Relaying

Event	SEL Relay Clock (Standard Time)	Relative Time (Seconds)
Fault on River St. Transformer secondary winding	05:52:37	0
Line 03 Overcurrent Relay picks up	05:52:37.761	0
Line 03 Overcurrent Relay Sends trip to 7B1 and 7B2	05:53:29.166	51.405
7B2 Trips	05:53:29.241	51.480
7B1 Trips	05:53:29.311	51.550
Flagg Pond – 7B1 breaker recloses	05:53:34.440	56.679
Line 03 Overcurrent Relay picks up	05:53:34.536	56.775
Fault in Transformer Primary winding (Current jumps from appr. 1000 Amps to 5000 Amps)	05:54:01.341	83.552
Line 03 Overcurrent Relay Sends Trip to 7B1 and 7B2	05:54:01.524	83.763
7B1 Trips	05:54:01.653	83.892
7B1 Closed (manually)	06:15:49.128	23 Minutes, 11 Seconds
7B2 Closed (manually)	06:15:53.140	23 Minutes, 15 Seconds

Appendix B

Fault Current Graphs


Flagg Pond Currents: June 25, 2001- 05:53:58.943
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IC
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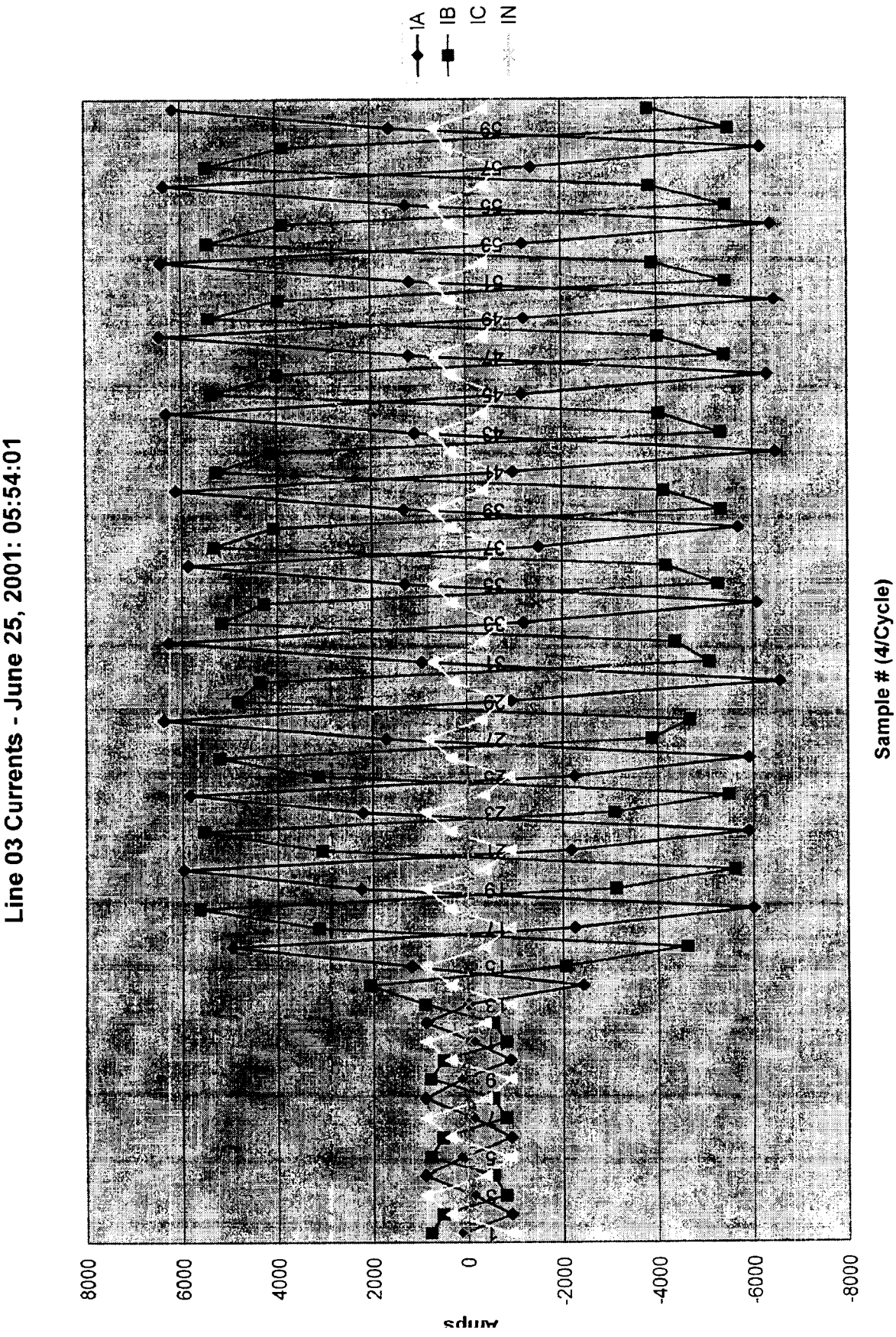
1000
500
0
-500
-1000
-1500
Amps
Sample # (4/Cycle)


Line 03 Currents - June 25, 2001: 05:54:01
IA
IB
IC
IN
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
amps
Sample # (4/Cycle)